Dark Energy as Cosmic Temporal Tension

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Abstract

This paper presents a dedicated, comprehensive formulation of dark energy within the Granular Cosmic Vacuum (GCV) framework. In contrast to the standard view that associates dark energy with a cosmological constant, a scalar field, or quantum vacuum energy, the GCV model interprets dark energy as the temporal tension of a closed cosmic string that constitutes the structure of cosmic time in the intergalactic domain. The fundamental tension scale is set by Planck physics and is geometrically damped across many hierarchical levels, from the Planck length to the Hubble radius, yielding the observed dark-energy density $\rho_\Lambda \approx 10^{-9}$ J/m^3 without fine-tuning or quantum vacuum contributions. We develop the ontology of the temporal string, define its structural damping through an exponential map, derive the effective energy density and equation of state, and clarify why the traditional cosmological constant problem arises from a category mistake between distinct physical domains. We also outline observational consequences, in particular an additional, small damping effect on high-energy gamma rays that propagate through the granular vacuum, providing a falsifiable prediction of the temporal-tension model of dark energy.

Keywords— dark energy; cosmic temporal tension; granular cosmic vacuum; temporal string; structural damping; cosmological constant problem; gamma-ray attenuation.

1 Introduction

The accelerated expansion of the universe is commonly attributed to a dark-energy component that constitutes about 70% of the total energy budget. In the standard ΛCDM model, this dark energy is modeled phenomenologically by a cosmological constant Λ with equation of state $w \simeq -1$, or by a dynamical scalar field whose potential is adjusted to mimic this behavior. Another widespread interpretation equates Λ with quantum vacuum energy obtained by summing zero-point energies of quantum fields. However, this leads to the well-known cosmological constant problem: the quantum-field-theoretic estimate of vacuum energy, $\rho_{\text{vac,QFT}}$, exceeds the observed dark-energy density $\rho_{\Lambda,\text{obs}} \sim 10^{-9}$ J/m^3 by about 10^{120}–10^{122}.

The Granular Cosmic Vacuum (GCV) framework offers a different starting point. It rejects the assumption that the intergalactic vacuum is a smooth QFT vacuum and instead postulates a granular structure composed of microscopic white holes stabilized by

contracted temporal strings. In this setting, dark energy is not a substance or field; it is a purely geometric phenomenon: the tension of cosmic time encoded in a closed temporal string spanning the intergalactic domain. This paper focuses exclusively on this temporal-tension interpretation of dark energy, providing a complete theoretical and mathematical account.

2 Domains and Ontology of the Temporal String

2.1 Three physical domains

In the full GCV picture, the universe is partitioned into three ontologically distinct domains:

- **P1:** Galactic interiors, where space-time is described by General Relativity and matter by Quantum Field Theory. A Hilbert space exists, quantum states and entanglement are defined, and the Standard Model holds.
- **P2:** The intergalactic "desert", where there is no global QFT vacuum, no global Hilbert space, and no virtual particles. Instead, the fundamental structure is a lattice of microscopic white holes (MWs) stabilized by contracted temporal strings.
- **P3:** Galactic edges and halos, where closed spatial membranes generate effective gravitational fields that reproduce dark-matter-like phenomenology without invoking new particles.

Dark energy belongs to the ontology of P2: it is a property of the temporal structure of the cosmos outside galaxies, not a quantum effect inside P1.

2.2 The temporal string as a geometric entity

In domain P2, cosmic time is not just a parameter; it has a geometric embodiment as a closed temporal string. The main features of this string are:

- It is a purely temporal geometric object: a closed loop in the cosmic temporal dimension t_{cosmic}, distinct from the local time coordinate used inside galaxies.
- It is not a superstring-theory string: there are no quantized vibrational modes or higher-dimensional embedding; it is classical and geometric.
- It is not embedded in a pre-existing manifold; the string constitutes the temporal structure of P2 rather than living in it.
- It is formed by a ternary composition rule ($3 \to 1$): three contracted temporal strings combine to produce a single closed temporal string. This reflects a structural postulate, analogous in spirit to the role of gauge groups in the Standard Model.

The defining physical property of this temporal string is its tension, which is identified as the fundamental origin of dark energy.

3 Fundamental Tension and Structural Damping

3.1 Planck-scale tension

At the deepest level, the natural tension scale is set by Planck units. The Planck length is

$$\ell_P \approx 1.6 \times 10^{-35} \text{ m},$$

and the corresponding Planck tension is

$$T_P = \frac{c^5}{G\ell_P} \sim 10^{70} \text{ J/m}.$$

This quantity represents the intrinsic tension of a geometric string at the Planck scale, analogous to the Planck energy or Planck force in standard dimensional analysis.

3.2 Structural damping from Planck to Hubble scales

The observed dark-energy density is many orders of magnitude smaller than what would result from a raw Planck-scale tension. In the GCV framework, this discrepancy is not resolved by fine-tuning, but by a natural structural damping process as the temporal string is coarse-grained from the Planck scale to the Hubble scale.

Let $R_H = c/H_0$ denote the Hubble radius, where H_0 is the present Hubble constant. We model the effective cosmic tension as a power-law damped version of the Planck tension:

$$T_{\text{cosmic}} = T_P \left(\frac{R_H}{\ell_P} \right)^{-\lambda_{\text{struct}}}, \quad 0 < \lambda_{\text{struct}} < 1.$$

The exponent λ_{struct} encodes the cumulative effect of many hierarchical levels of geometric reorganization of the temporal string as the universe expands.

3.3 Exponential damping map

Equivalently, one can express the damping process in terms of an exponential map γ acting on the tension each time the universe undergoes an e-fold of expansion. If N is the number of e-folds from the Planck era to the present (of order $N \sim 140$) and λ is a characteristic damping rate per e-fold, we can write:

$$\gamma(T) = Te^{-\lambda}, \quad \gamma^N(T_P) = T_P e^{-\lambda N}.$$

Defining the cosmic damping factor

$$\Gamma_{\text{cosmo}} = e^{-\lambda N},$$

we obtain

$$T_{\text{cosmic}} = T_P \Gamma_{\text{cosmo}}.$$

Typical values of λ and N give $\Gamma_{\text{cosmo}} \sim 10^{-53}$, which, when combined with T_P, yields the correct order of magnitude for the observed dark-energy density.

4 Dark-Energy Density from Temporal Tension

4.1 Energy density associated with cosmic tension

The dark-energy density is interpreted as the energy per unit comoving volume associated with the cosmic temporal tension. For a characteristic cosmic length scale of order the Hubble radius R_H, a natural expression is:

$$\rho_\Lambda = \frac{T_{\text{cosmic}}}{R_H}.$$

Substituting the expression from Section 3.2, we obtain:

$$\rho_\Lambda = \frac{T_P}{R_H}\left(\frac{R_H}{\ell_P}\right)^{-\lambda_{\text{struct}}} \approx 10^{-9}\ \text{J/m}^3.$$

This matches the observed dark-energy density without any reference to vacuum fluctuations or scalar fields. The smallness of ρ_Λ compared to Planck-scale quantities is explained by the large ratio R_H/ℓ_P raised to the negative structural exponent.

4.2 Contribution to Einstein's equations

In Einstein's field equations, the temporal string tension appears as an effective stress-energy tensor of the form:

$$T_{\mu\nu}^{(\text{tension})} = -T_{\text{cosmic}} g_{\mu\nu}.$$

This is equivalent to introducing an effective cosmological constant

$$\Lambda_{\text{eff}} = \frac{8\pi G}{c^4} T_{\text{cosmic}},$$

and yields an equation of state

$$w = \frac{p}{\rho_\Lambda} \approx -1,$$

in agreement with the observations of accelerated expansion. In this view, the cosmological constant is not a free parameter or vacuum energy, but the macroscopic imprint of temporal string tension.

5 Why There is No Cosmological Constant Problem

The traditional cosmological constant problem arises from an implicit identification between $\rho_{\text{vac,QFT}}$, calculated within quantum field theory, and the observed $\rho_{\Lambda,\text{obs}}$ that drives cosmic acceleration. In the GCV model, this identification is invalid for two reasons:

1. **Different domains:** $\rho_{\text{vac,QFT}}$ is defined in domain P1, where QFT and a local Hilbert space exist (inside galaxies). The observed ρ_Λ is a property of domain P2, where no QFT vacuum or global Hilbert space exists and where the relevant structure is a classical temporal string.

2. **Different ontologies:** $\rho_{\text{vac,QFT}}$ arises from quantum fluctuations of fields in space-time, while ρ_Λ in this model arises from geometric tension of cosmic time. They are distinct physical quantities, not to be directly compared.

Therefore, the huge discrepancy between $\rho_{\text{vac,QFT}}$ and $\rho_{\Lambda,\text{obs}}$ is interpreted as a *category error*: a mistake of comparing quantities from different physical domains and different ontological levels.

6 Observable Consequences: Gamma-Ray Attenuation

Although dark energy in this model is geometric rather than particulate, it leaves observable signatures in the propagation of high-energy radiation through the intergalactic domain P2. When a photon leaves a galaxy (P1) and enters the intergalactic vacuum (P2), it ceases to be a QFT photon and becomes a string photon: a wave of temporal tension on the closed string network. Its propagation is then affected by the granular structure of the cosmic vacuum.

In standard ΛCDM, the flux of a high-energy gamma ray of energy E from redshift z is

$$F_{\Lambda\mathrm{CDM}}(E,z) = \frac{F_{\mathrm{em}}(E)}{4\pi D_L^2(z)} \exp[-\tau_{\mathrm{pair}}(E,z)],$$

where $F_{\mathrm{em}}(E)$ is the emitted spectrum, $D_L(z)$ the luminosity distance, and $\tau_{\mathrm{pair}}(E,z)$ the optical depth for $\gamma\gamma \to e^+e^-$.

In the GCV framework, an additional small damping factor appears due to string-photon propagation through the granular temporal string network:

$$\Gamma(D,E,\gamma_N) = \exp\left[-\gamma_N f(D,E)\right],$$

with

$$f(D,E) = \left(\frac{D}{\ell_g}\right)^{\alpha} \left(\frac{E}{E_0}\right)^{\beta}, \quad \gamma_N \ll 1,$$

where ℓ_g is the vacuum-granule scale, E_0 is a reference energy and α, β are positive exponents. The observed flux becomes

$$F_{\mathrm{obs}}(E,z) = F_{\Lambda\mathrm{CDM}}(E,z)\,\Gamma(D_L(E,z),E,\gamma_N),$$

and the residual ratio

$$R(E,z) = \frac{F_{\mathrm{obs}}(E,z)}{F_{\Lambda\mathrm{CDM}}(E,z)} = \exp\left(-\gamma_N \left(\frac{D_L}{\ell_g}\right)^{\alpha} \left(\frac{E}{E_0}\right)^{\beta}\right)$$

provides a concrete, testable prediction. Deviations of $R(E,z)$ from unity, with the predicted distance and energy dependence, would support the temporal-tension model, while null results would constrain the parameters γ_N and ℓ_g.

7 Conceptual Summary

In this dedicated paper on dark energy as cosmic temporal tension, the key points are:

- Dark energy is reinterpreted as the tension of cosmic time, not as vacuum energy, a scalar field, or an exotic fluid.
- The underlying object is a closed temporal string that constitutes the intergalactic temporal structure in domain P2.
- The fundamental tension scale is $T_P \sim 10^{70}$ J/m, damped structurally by geometric factors from the Planck scale to the Hubble radius.

- The resulting dark-energy density $\rho_\Lambda = T_{\text{cosmic}}/R_H$ matches the observed value $\sim 10^{-9}$ J/m^3 without fine-tuning.
- The cosmological constant problem is resolved conceptually by recognizing that $\rho_{\text{vac,QFT}}$ and ρ_Λ belong to different domains and ontologies.
- The model yields testable predictions in high-energy gamma-ray astronomy via an additional, distance-dependent attenuation effect.

Thus, the temporal-tension interpretation transforms dark energy from an unexplained parameter into a measurable geometric property of the universe's temporal structure.

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